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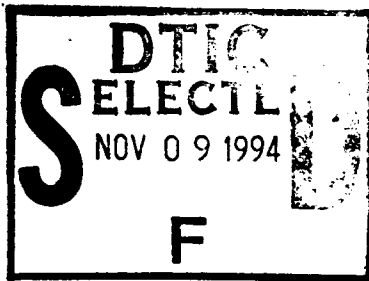


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**The Interactive Multisensor Analysis
Training (IMAT) System: A
Formative Evaluation in the Aviation
Antisubmarine Warfare Operator (AW)
Class "A" School**



**John A. Ellis
Steven Parchman**

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13. ABSTRACT (Maximum 200 words) The IMAT is an innovative computer-based instructional approach developed to teach complex cognitive concepts and skills. When it was introduced into the Aviation Antisubmarine Warfare "A" School the curriculum was revised to accommodate the added instructional capabilities. The instructional design, motivational characteristics, and comparative effectiveness of the revised Acoustical Oceanography lesson of the new curriculum were evaluated. The results revealed few serious problems or deficiencies. The only major problem for the IMAT course was a high number of untested use/cognitive performance objectives. This was the result of the application of standard testing procedures by the AW "A" School and was not a product of the IMAT design and development process. The motivational analysis showed high positive scores for the IMAT instruction compared to similar scientific content. The IMAT course and previous course did not differ on comparable test items, however, the test items that could be compared did not focus on cognitive concepts and skills.					
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Foreword

The evaluation of the Aviation Antisubmarine Warfare Operator (AW) "A" School's Acoustical Oceanography lesson work was conducted under the 6.3 Manpower, Personnel, and Training Advanced Technical Development Program Element 0603707N (Work Unit 063707N.L2335.IM001) and the the 6.2 Mission Support Technology Program Element 0602233N, (Personnel and Training Technology Block, NP2A Work Unit 0602233N.RM33T23.08) which was sponsored by the Chief of Naval Research (Code-34). The goal of this study was to evaluate the lesson's instructional design and development, motivational characteristics, and effectiveness.

The recommendations provided in this report are intended for use by Officer in Charge, Avionics Department, Naval Air Technica' Training Center.

Any questions regarding this report should be addressed to Dr. John Ellis, Instructional Sciences Division, (619) 553 9273 or DS : 553 9273.

J. C. McLACHLAN
Director, Training Research Department

Summary

Background and Problem

Job requirements for Navy system operators include computation, analysis, classification, interpretation, decision making, and communication. Technical competency in these types of tasks depends upon the acquisition and retention of the organized/systematized technical knowledge and skills underlying performance. Unfortunately, there is evidence that these types of tasks may not be well taught or remembered.

Recently, innovative computer-based instructional approaches have been developed to teach the complex cognitive concepts and skills involved in aviation based anti-submarine warfare (ASW). Specifically, the Interactive Multisensor Analysis Trainer (IMAT) has been introduced into the Aviation Antisubmarine Warfare Operator (AW) "A" school and the curriculum has been revised to accommodate the added instructional capabilities. The IMAT was designed to facilitate learning by graphically elaborating complex cause and effect relationships, visibly depicting invisible phenomena, and providing a mission oriented context for demonstrations, examples, and practice during the course of instruction.

Objectives

The objectives of this effort were to: (1) evaluate the instructional design/development of the IMAT instruction and the previous AW "A" school instruction which was delivered in the standard lecture format, (2) assess the motivational characteristics of the IMAT instruction, and (3) where possible, compare the effectiveness of IMAT instruction with the previous AW "A" school instruction.

Method

The instructional design evaluation used the Course Evaluation System (CES) to assess the consistency (match) among learning objectives, test items and the instructional presentation and adequacy of the instructional presentation for the IMAT course. For comparative purposes the CES was used to evaluate the consistency of the same components for the previous standard lecture course.

To assess the motivational characteristics of the IMAT instruction a questionnaire containing four separate scales was given to 76 students after they completed the unit exam. The questionnaire was designed to assess attention, relevance, confidence, and satisfaction.

Finally, IMAT students and students who had taken the previous standard lecture course were compared on test scores on selected items.

Results

Overall the instructional design evaluation for both the IMAT and the standard lecture course revealed few serious problems or deficiencies. Both courses were found to be superior to the typical Navy course. The only major problem for the IMAT course was a high number of untested objectives requiring trainees to perform procedural and cognitive tasks. This was the result of the application of standard testing procedures by the AW "A" School and was not a product of the IMAT design and development process. The motivational questionnaire analysis showed high positive scores on all four scales for the IMAT course. When compared to a recently redesigned course on electricity theory the IMAT course was superior to several different computer-based delivery strategies. Finally, end-of-course performance for the IMAT course and previous standard lecture course did not differ on selected test items. However, both the IMAT and standard lecture course tests emphasized remembering facts. The IMAT course is longer and was designed to teach more qualitative knowledge, higher level concepts, and application skills than the standard lecture course. Qualitative knowledge, concepts and skills were not tested in either course and the full effectiveness of the IMAT system can not be assessed unless this type of information is tested.

Recommendations

1. The AW "A" school should implement the changes and corrections identified in the CES analysis.
2. The AW "A" school should develop test items to assess cognitive concepts, relationships, and skills and revise the current Acoustical Oceanography tests.
3. Evaluation of IMAT training should continue as IMAT is introduced into additional schools. Pre-post performance data should be collected as well as motivational and instructional quality data. Future evaluations should include the assessment of cognitive skills and qualitative understanding in addition to factual knowledge.

The Navy Personnel Research and Development Center is providing support in accomplishing these recommendations as part of ongoing project efforts.

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Introduction

Background and Problem

The learning and retention of complex cognitive knowledge and skills are essential in today's highly variable operational environment. For example, sonar system operators must detect, classify, track, and target submarines under a variety of conditions and constraints. Operation of sonar and other similar systems requires computation, analysis, classification, interpretation, decision making, and communication skills. Technical competency in performing these types of tasks depends upon the acquisition and retention of the technical knowledge and skills required to perform them.

Unfortunately, evidence from research on science education and military technical training indicates that these types of tasks may not be well taught or remembered (Dick, Parker, & Koehler, 1990; Druckman & Bjork, 1991; McKeithen & Reitman, 1981; Riley, 1986; Semb & Ellis, 1994; Wetzel, Konoske, & Montague, 1983). Several recent research programs have attempted to address these problems through the development of instructional strategies and methods designed to facilitate the learning of complex knowledge and skills (Cognition and Technology Group at Vanderbilt, 1990; Collins, Brown, & Newman, 1989; Konoske & Ellis, 1991). Recently, an innovative computer-based instructional approach based on many of these strategies has been developed to teach the complex cognitive concepts and skills involved in aviation based anti-submarine warfare (ASW) (Wetzel-Smith, 1991). Specifically, the Interactive Multisensor Analysis Training system (IMAT) has been introduced into the Aviation Antisubmarine Warfare Operator (AW) class "A" school and the curriculum has been revised to accommodate the added instructional capabilities. Strategies incorporated in the new curriculum include a situated, anchored, or contextualized approach to teaching cognitive concepts and skills (Cognition and Technology Group at Vanderbilt, 1990; Collins et al., 1989) and techniques that provide visually, verbally, and textually elaborated explanations for complex relationships and phenomena. Such strategies have been shown to improve learning (Konoske & Ellis, 1991; Whitehill & Ellis, in process). There is also some evidence that the innovative methods being used in the new course may differentially affect retention (Semb & Ellis, 1994).

Objective

The objectives of this effort were to: (1) evaluate the instructional design/development of the IMAT and previous standard lecture instruction; (2) assess the motivational characteristics of the IMAT instruction; and (3) where possible, compare the effectiveness of IMAT instruction with the previous AW "A" school instruction using performance on comparable test items.

Method

Instructional Design/Development Evaluation

The Course Evaluation System (CES) (Ellis, Knirk, Taylor, & McDonald, 1993) was used to evaluate the instructional design and development of the IMAT and standard lecture instruction. The CES assesses the consistency (match) among learning objectives, test items, and the instructional presentation and the adequacy of the instructional presentation. The CES was applied to the objectives, test items, student guide, instructor guide, and instructional presentation for Unit Seven: Acoustical Oceanography of the Aviation Antisubmarine Warfare Operator (AW) Class A1 Course. For the previous standard lecture course only the objectives, test items, student guide, and instructor guide were evaluated because the instructional presentation was no longer given.

The CES classifies the course objectives using a scheme that corresponds to the general distinction between knowledge and skills. Because the AW course is an introductory course that emphasizes acoustical oceanography theory, as well as applications of that theory to anti-submarine warfare, the scheme was modified slightly to include two types of knowledge objectives and one type of skill objective. Course objectives were classified in one of the following categories:

Remember Fact. The student must recall or recognize names, definitions, steps of procedures, formulas and terms in formulas, labels for graphical display, or technical terminology.

Remember Qualitative Information. The student must recall or recognize cause and effect relationships, predictive and diagnostic information, or how and why explanations of events (e.g., diurnal effect), phenomena (e.g., bottom bounce), and devices (e.g., sensors).

Use Procedures and Rules. The student must perform a sequence of steps in a certain order to solve a problem, operate or maintain equipment, calculate or determine a value, or evaluate a scenario.

For details of the CES procedures and the underlying rationale see Ellis, Knirk, Taylor, and McDonald (1987, 1993).

Motivational Analysis

For the motivational analysis a questionnaire based on the Attention-Relevance-Confidence-Satisfaction (ARCS) motivational assessment model developed by Keller (1992) was developed. The 34 item questionnaire, designed for application to technical training, was administered to 76 AW "A" school students upon completion of the Unit Seven comprehensive test. The ARCS questionnaire assess four motivational characteristics; attention, confidence, relevance, and satisfaction. The attention oriented questions assess how well the material captures the interest of the learners and stimulates their curiosity to learn. The relevance questions address how well the materials meet the needs and goals of the learner. The confidence questions ask the students to report on their beliefs and feelings about well they will succeed and how much they can control

their own success. The satisfaction questions concern students feelings of reward and accomplishment and their enjoyment of the materials. The four scales are scored from 1 to 5 with 1 indicating a statement about the course is "Not true" and a 5 indicating a statement is "Very true." A score of 3 indicates students believe a statement is "Moderately true."

Comparative Analyses

Where possible the IMAT based instruction for Unit Seven was compared with the standard lecture instruction AW "A" school instruction on acoustical oceanography. The first comparison was to apply the CES to as much of the standard lecture course as possible. As discussed, this analysis included the learning objectives, test items, instructor guide and student guide from the previous standard lecture course. The results of this analysis were compared to the CES analysis on the IMAT course. The CES analysis on the IMAT course was also compared to data obtained in a larger analysis of 100 Navy courses to determine how the IMAT course compared to a "typical" Navy course.

The second comparison was designed to determine how well the standard lecture course students performed on the IMAT course objectives compared to IMAT course students. To accomplish this analysis test items from the standard lecture course that tested the IMAT course objectives were identified. Performance on the standard lecture course items that tested IMAT course objectives was compared to performance on the IMAT course test items for the same objectives.

The third comparison was designed to determine how well IMAT course students performed compared with the standard lecture course students on the standard course objectives. To accomplish this analysis test items from the IMAT course that tested the standard lecture course objectives were identified and test performance for the two student groups was compared.

Results and Discussion

Instructional Design/Development Analysis

The top half of Table 1 presents the results of the CES objective and test item evaluation for the IMAT course. The major finding is that a substantial number of Remember Qualitative information objectives and Use Procedure and Use Rule objectives are not tested. This frequently occurs in Navy schools (Taylor, Ellis, Baldwin, 1988) and can be corrected by developing additional test items and revising existing tests. This lack of test coverage did not result from the IMAT course development process. The tests for IMAT Unit Seven were developed by AW "A" school after the unit was delivered to the school. The tests developed at the school were consistent with traditional Navy classroom tests which emphasize fact oriented multiple-choice questions (Taylor et al., 1988). The development of more sophisticated test items designed to test complex cognitive relationships and skills is more difficult to do, especially in a multiple-choice format. Further, scoring for higher level items that are not in the

traditional multiple-choice format is also difficult. In any case, to assess the effectiveness of the IMAT course in teaching cognitive concepts, relationships, and skills, additional test items need to be developed and the current tests need to be modified and/or revised.

The finding that a high proportion of Remember Fact and Remember Qualitative information objectives did not have matching test items is attributable to many objectives written using the action verbs "state" and "define." These verbs require fill-in-the-blank, short answer, or essay test items. All the test items for the IMAT course used the multiple-choice format. This discrepancy is easily corrected by adding "recognize" or "select the ..." to the objective verbs.

The top half of Table 2 presents the objective and presentation consistency results for the IMAT course. The major finding is that for a small percentage of each type of objective the practice component of the presentation was either incomplete or not present. This can be corrected by developing practice test items for these objectives.

The CES adequacy criteria and instructional effectiveness checklist were also applied to the IMAT course and no deficiencies were identified.

Motivational Analysis

The ARCS questionnaire assesses four motivational characteristics; attention, confidence, relevance, and satisfaction. Each characteristic is rated from one to five; not true to very true, respectively. The mean scores for each scale for the IMAT course are: Attention = 3.43, Confidence = 3.36, Relevance = 3.76, and Satisfaction = 3.48.

Although it was not possible to collect ARCS data on the standard lecture course, recent ARCS data are available for a similar course employing computer-based instructional strategies. ARCS questionnaires were given to students completing a lesson on circuits of the Aviation Electronics Technician "A" School course. This lesson is similar in complexity to the Acoustical Oceanography lesson. Four different methods were used to present the circuits lesson: (1) conventional classroom instruction, (2) computer-based drill and practice, (3) enhanced computer-based instruction (CBI) (similar to IMAT but individualized instead of lecture based), and (4) a computer-based adventure game designed to teach concepts and problem solving. The three CBI conditions were developed for a research project and were designed to be state of the art training. Special consideration was given to the motivational aspects of this training, especially in the adventure game condition. Thus, the CBI groups provide a fair motivational comparison for classroom based IMAT training. If anything, the IMAT training is at a disadvantage because it is not individualized. A one-way analysis of variance and post-hoc paired comparisons compared on the four groups from the Aviation Electronics course and IMAT students. Students rated IMAT instruction significantly higher than classroom instruction, drill CBI, and game CBI on relevance, confidence, and satisfaction. There were no differences between IMAT and the enhanced CBI (the condition most similar to IMAT) on any scales and no difference between IMAT and the game CBI on attention. These findings show that IMAT is as motivating as similarly designed individualized CBI and more motivating than traditional classroom instruction and standard drill and practice CBI. Table 3 presents the means for the RC circuit lessons and the IMAT lesson.

Table 1
IMAT and Previous Standard Lecture Course Objective
and Test Item Evaluation Results

IMAT Course			
Rating Category	Remember Fact (%) <i>Objectives n=54</i> <i>Test Items n=138</i>	Remember Qualitative (%) <i>Objectives n=19</i> <i>Test Items n=15</i>	Use (%) <i>Objective n=17</i> <i>Test Items n=17</i>
Objective Not Appropriate	0	0	0
Objectives Not Essential	0	0	12
Objectives Not Tested	22	58	71
Test Items Don't Match Objective	62	33	12
Conditions Don't Match	59	12	2
Standards Don't Match	0	0	0
Actions Don't Match	62	33	12
Test Items Not Adequate	0	0	0
Test Items Not Appropriate	0	0	0

Previous Standard Lecture Course			
Rating Category	Remember Fact (%) <i>Objectives n=13</i> <i>Test Items n=47</i>	Remember Qualitative (%) <i>Objectives n=2</i> <i>Test Items n=12</i>	Use (%) <i>Objective n=5</i> <i>Test Items n=14</i>
Objective Not Appropriate	0	0	0
Objectives Not Essential	0	0	0
Objectives Not Tested	8	0	0
Test Items Don't Match Objective	100	100	100
Conditions Don't Match	11	0	7
Standards Don't Match	100	100	100
Actions Don't Match	11	0	50
Test Items Not Adequate	0	0	0
Test Items Not Appropriate	0	0	0

Table 2
Presentation Consistency for the IMAT and Previous Courses

IMAT Course				
Objective Type	Required Presentation Components			
	Statement	Practice Remembering w/Feedback	Examples	Practice Using w/Feedback
Remember Fact % Incomplete % Not present <i>n</i> = 54	0 0	12 6	NA NA	NA NA
Remember Qualitative % Incomplete % Not present <i>n</i> = 19	0 0	16 5	NA NA	NA NA
Use % Incomplete % Not present <i>n</i> = 17	0 0	0 0	0 0	0 12

Previous Course				
Remember Fact % Incomplete % Not present <i>n</i> = 13	0 0	15 15	NA NA	NA NA
Remember Qualitative % Incomplete % Not present <i>n</i> = 2	0 50	0 50	NA NA	NA NA
Use % Incomplete % Not present <i>n</i> = 5	0 20	0 0	0 20	0 0

note: NA = not applicable.

Table 3
ARCS Means for the RC Circuit and IMAT Lessons

GROUP	Attention	Relevance	Confidence	Satisfaction
Classroom	2.84	3.05	3.06	3.06
Drill CBI	3.02	3.38	2.93	2.74
Enhanced CBI	3.71	3.54	3.56	3.22
Game CBI	3.48	3.38	2.66	3.00
IMAT	3.43	3.76	3.36	3.48

Comparative Analysis

Course Evaluation System Comparisons

The bottom halves of Tables 1 and 2 present the objective test item analysis and presentation consistency analysis for the standard lecture course. For this course only one objective was not tested. However, none of the objectives and test items matched because each objective required a performance standard of no errors while the course test had a passing standard of 80%. This deficiency is correctable by changing the standard for either the objectives or the course test. The consistency findings show missing practice for a small percentage of the the Remember Fact objectives and for one of the two Remember Qualitative information objectives. Presentation adequacy and instructional presentation checklist evaluations could not be performed on the standard lecture course because these analyses require classroom observations and the course is no longer given. Overall the findings for the standard lecture course and the IMAT course are similar. There are no major consistency discrepancies and no serious problems with the objective and test items matches. The most serious discrepancy is the large number of untested higher level knowledge and skill objectives in the IMAT course. However, this finding is typical of many Navy courses. In a CES evaluation of 100 Navy courses Taylor et al. (1988) found that almost 50% of the objectives evaluated were not tested. Additionally, for those objectives that were tested almost 50% had test items that did not match. In addition, unlike the AW courses, over half of the objectives and over one third of the test items were found to be not appropriate. In general, both the IMAT course and the standard lecture course are superior to the typical Navy course based on the CES criteria.

While the IMAT and standard lecture course are similar based on the CES analysis there are some quantifiable differences between them that indicate a substantial change in the instructional approach in the IMAT course. First, there is the IMAT trainer, which uses computer technology to illustrate and contextualize complex concepts and skills. Second, the total number of objectives in the IMAT course (not counting lesson terminal objectives) is 90 versus 20 in the standard lecture course. This is the result of a more thorough front-end analysis of the knowledges and skills that need to be taught. As a result, the course length for the IMAT course is 58 classroom periods versus 26 periods

for the standard lecture course. Finally, there are proportionately fewer Remember Fact and more Remember Qualitative information objectives in the IMAT course than in the standard lecture course. This reflects a concern for teaching the complex cognitive concepts and relationships needed to perform in an increasingly technological work environment.

Test Performance Comparisons

The end of course tests for the standard lecture course and IMAT course were different. In order to compare performance two different test item matches were performed. First, test items from the old course were matched with the IMAT course objectives and second, test items from the IMAT course were matched with the old course objectives. For the first comparison an overall score was computed for the old test items that matched IMAT course objectives. There were 62 out of a possible 74 standard lecture course test items that matched. The 62 items tested 22 of the 90 IMAT course objectives. The overall score for the 62 standard lecture course test items was compared to an overall score for the 70 IMAT course test items that tested the same objectives. The overall score for standard lecture course test items was 86.65% compared to 86.57% for the IMAT test items. There were no differences between the two courses on this measure, therefore, an objective by objective comparison was not performed.

For the second comparison, an overall score was computed for the IMAT test items that matched standard lecture course objectives. There were 73 out of a possible 168 IMAT course test items that matched. The 73 items tested 13 of the 20 standard lecture course objectives. The overall score for the 73 IMAT course test items was compared to an overall score for the 58 standard lecture course test items that tested the same objectives. The overall score for standard lecture course test items was 86.27% compared to 86.42% for the IMAT test items. Overall there were no differences between the two courses on this measure, therefore, an objective by objective comparison was not performed.

The high overall scores and lack of performance differences between the courses on items testing the other course's objectives indicates that each course is effectively teaching the information tested. Recall, however, that both the IMAT and standard lecture course tests emphasized remembering facts. Recall also that the IMAT course is longer and was designed to teach more qualitative knowledge, higher level concepts, and application skills than the standard lecture course. Qualitative knowledge, concepts and skills were not tested in either course and the full effectiveness of the IMAT system can not be assessed unless this type of information is tested.

Recommendations

1. The AW "A" school should implement the changes and corrections identified in the CES analysis.
2. The AW "A" school should develop test items to assess cognitive concepts, relationships, and skills and revise the current Acoustical Oceanography tests.
3. Evaluation of IMAT training should continue as IMAT is introduced into additional schools. Pre-post performance data should be collected as well as

motivational and instructional quality data. Future evaluations should include the assessment of cognitive skills and qualitative understanding in addition to factual knowledge.

The Navy Personnel Research and Development Center is providing support in accomplishing these recommendations as part of ongoing project efforts.

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